POWER SUPPLY WITH DISCONNECT FUSE

The invention relates to a power supply in which a feed voltage is routed via at least one series arm to at least one output, the at least one arm having a disconnect fuse formed as a controlled semiconductor switch and a monitoring unit being set up to send a disconnect signal to the semiconductor switch in the event of changes in voltages or currents past given tolerance values.

In industrial systems and in automated systems, it is of particular significance that the feed voltages of the individual loads or load groups are supplied according to special safety criteria. In particular, it is of primary importance that information processing parts of a control system, such as microprocessor subassemblies, must be supplied with the needed power in the event of a power failure. In many industrial applications, the feed voltage is 24 volts d.c., but other d.c. values are also typical, and even a.c. voltages, such as 115, 230 or 24 volts, are used.

Short circuits or overloads in partial areas of a control system, for example, in the output peripherals, can easily result in a complete, albeit usually only brief, failure of the feed voltage of the control system, which often leads to a loss of data in the central control units that are supplied by the feed voltage.

The increasing use of switched mode power supplies highlights this problem since, because of the sensitive electronics, the internal control circuits limit the output current to values only slightly higher than the nominal current. There exists in particular the problem that conventional fuses for the individual outputs are unable to disconnect in a sufficiently brief period of time. For rapid disconnection, fuses or circuit breakers often require a multiple of their nominal current. However, the switched mode power supplies cannot supply this in addition to

the remaining load, so that the total feed voltage bursts in – even before a fuse triggers and the faulty output or branch is cleared.

According to the older application PCT/AT 00/00318 of the applicant, the use mentioned at the outset of controlled semiconductor switches is therefore provided. A circuit of this type is explained below in relation to Figure 1.

According to Figure 1, a switched mode voltage transformer SPW supplies an output or feed voltage U_s, for example 24 volts, to ground. Such voltage transformers or switched mode power supplies are known to one skilled in the art in a multitude of designs and in and of themselves do not constitute the subject matter of the present invention. For the most part, an input a.c. voltage, for example 230 volts, is rectified and the resulting d.c. voltage is fed via a cycled switch to a primary winding of a transformer. A rectification of the feed voltage is repeated in secondary circuit. Voltage transformer SPW operates, for example, as flyback or flux converter and is usually regulated to a constant output voltage. However, it must be emphasized that the invention is not confined to specific transformers and that the feed voltage, for example can also be a regulated or unregulated a.c. voltage.

Feed voltage U_s is fed to a first output A_1 via a conventional fuse Si1 a controlled switch SW1 and via a measuring shunt RM1. Output voltage U_{A1} is applied to output A1. In the same manner, feed voltage U_s is fed to an output A_2 and an output A_3. Fuses $S_i1 - S_i3$ are, for example, fusible cutouts and are provided primarily if this calls for standard safety determinations, primarily for fire protection. However, they are not of any significance for the function of the invention.

Fed to a monitoring unit UWE are, on the one hand, feed voltage U_s, which is compared in a comparator KOM to a reference voltage U_{Ref}, and, on the other hand, any of the voltages

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occurring on the measuring shunts that are proportional to the output voltages, for example U_{i3r},

for the comparison in switching amplifiers, for example SV_3. The shown circuit, when connected

to a sequencing control (not shown), makes it possible to selectively disconnect outputs, when

the feed voltage bursts in, according to predetermined priorities or to disconnect individual

branches in the event of an overload. It is also possible to additionally or alternatively monitor

the output voltages $U_{A1}...U_{A3}$ and to call on them for disconnect operations. The control state in

question may be indicated, for example, by little lights $L1...L3$.

During normal operation, a switching transistor of a long branch is in an operating state in

which only a slight drop in voltage occurs; that is, the transistor is in saturation when there is a

longitudinal voltage of, for example, clearly under one volt. Accordingly, the power dissipation

of the transistor is not all that great. The cooling unit is also designed for such a continuous

power dissipation.

Then, if the limit current is exceeded, the transistor – together with the monitoring circuit

– begins to hold the output flow constant in order not to overload the feed source too much and

thus provoke a crash of the entire system. The saturation state is left and as a result a high power

dissipation is then carried out in the transistor, specifically in the extreme case short circuit

current times feed voltage. Because the transistor, for example of the MOSFET type, has already

been heated up during normal operation, the absorption of the additional power loss in the limit

state is problematic. On top of that, the limit state lasts a short period of time, for example 50 –

100 ms, then the disconnection occurs. In this short time, the heat cannot at all be passed on to a

heat sink and therefore must be absorbed by the transistor chip.

In order to prevent destruction of the switching transistor before disconnection, transistors

having very large chip surfaces must therefore be used, which results in high costs.

An object of the present invention is thus to provide a power supply in which the problem of expensive overdimensioning of the semiconductor switch no longer exists.

Starting from a power supply of the type mentioned at the outset, this objective is achieved according to the invention in that at least one auxiliary semi-conductor switch is connected in parallel that, in the event of an overload, absorbs a substantial portion of the overload current in the branch.

By employing the invention, the thermal "surge" is thus quickly transferred, before disconnection, onto the auxiliary transistor, which for this purpose is available without the aforementioned preliminary increase in temperature.

In an expedient variant, provision is made for the monitoring unit to be set up to keep the auxiliary semiconductor switch at least essentially disconnected during normal operation, but to switch it on in the event of an overload as the main semiconductor switch is simultaneously disconnected. In this way it is possible to affect the characteristic of the transition from the main switch to the auxiliary switch by appropriate design of the monitoring unit.

It is especially advantageous if a ballast resistor is connected in series with the auxiliary semiconductor switch. In this way, the majority of the heat is dissipated in the ballast resistor and the auxiliary semiconductor switch can be dimensioned for a lower power dissipation and therefore be cheaper. In the process it is advisable if the given short circuit current of the branch is determined essentially by the ballast resistor and the feed voltage so that $R1A \approx U_s/I_{K1}$.

In practice, it is expedient and economical if the semiconductor switches are of the FET type. In this manner, the triggering by the monitoring unit may be simplified. In so doing an especially simple solution in terms of circuitry is achieved if the semiconductor switches are of the self-locking FET type, the gate of the main semiconductor switch being connected to the

source and triggered by an output of the monitoring unit via a Zener diode, and the gate of the auxiliary semiconductor switch being directly triggered by the same output. A ballast resistor, which is formed as a composite carbon resistor, is especially well-suited to absorb the power impulse that occurs when there is a disconnection.

The invention, together with additional advantages, is explained in detail below in relation to embodiments that are presented as examples in the drawing. In them,

- Figure 1 shows a circuit of a power supply of the older application PCT/AT 00/00318, as already described above,

- Figure 2 shows a circuit of a first embodiment of the invention, and

- Figure 3 shows a circuit of a second embodiment of the invention.

According to Figure 2, which concerns only one branch of a circuit according to Figure 1, load LAS is connected across a semiconductor switch SW1, in this case a self-locking n-channel IGFET, to feed voltage U_s. As already explained with respect to Figure 1, a monitoring unit UWE, by corresponding signal to the gate of switch SW1, provides for the opening of the latter if, for example, the current measured using resistor R_{M1} exceeds a pre-definable maximum value. Variants of the disconnection conditions are possible, for example, a disconnection as a function of the output voltage or input voltage and combinations of such disconnection conditions.

The basic function of such an electronic fuse is to prevent a current of any given size from being able to flow through a branch. In reality, this is the typical function of a circuit breaker, with the additional characteristic that an operating state of the current limitation is still picked up before complete interruption of the current feed.

A system having several load branches that are supplied via an electronic fuse of this type is protected in this manner from a breaking in of the entire service voltage.

As mentioned, a disconnection of the individual branches may be carried out according to a pre-definable sequence, for example, in reaction to a drop in feed voltage U_s, for example, 24 V.

In addition, it may also be provided that, when a specific value of the feed voltage, e.g., 22 V, is undershot, that/those output(s) are disconnected that are routing more than 100% of the reference current at the moment when the threshold is undershot.

The invention then provides that an auxiliary semiconductor switch H1A, in the present case of Figure 2 also a self-locking n-channel field-effect transistor, is connected in parallel to semiconductor switch SW1. In this case another ballast resistor RA1, which, however, may also be eliminated as will be explained later, is connected in series with auxiliary switch H1A.

During normal operation, switch SW1 is conductive and the total current flows essentially through switch SW1 and through measuring shunt R_{M1} into load LAS'. In the event of a short circuit, a state similar to a short circuit or very generally when exceeding the pre-definable maximum current, the appropriately high current would flow until disconnection, for which a time period of, for example, 50 – 100 ms may be provided. In order to prevent destruction of switch SW1, which has already been heated up during normal operation, transistor SW1 is locked in the event of an overload and the current then flows through auxiliary switch H1A and ballast resistor RA1 until auxiliary switch H1A also receives a disconnect (lock) signal from monitoring unit UWE.

Assuming that ballast resistor RA1 has a comparatively higher resistance value than the forward resistance of switches H1A and SW1, the essential energy is dissipated in ballast resistor RA1 up until disconnection. In this way, not just main switch SW1 is protected against thermal destruction – it was already disconnected – but also auxiliary switch H1A.

Resistance RA1 also makes it possible, provided that there is a proper dimensioning, that auxiliary switch H1A may also remain continuously switched on during normal operation. This is the case anyway if the series circuit of ballast resistor RA1 – auxiliary switch H1A (switched on) has a resistance value that is greater than the forward resistance of main switch SW1. In practice, such as in the case of current limitation, approximately 80% of the leakage power occurring in ballast resistor RA1 was dissipated.

In an exemplary embodiment, the feed voltage is 24 V and the maximum short circuit current is 13 A. The total resistance of the auxiliary branch then turns out to be

$$R_{ges} = 24V/13A = 1.84 \text{ Ohm}$$

The resistance of auxiliary switch R_{on} is, for example, 0.1 Ohm so that ballast resistance RA1 turns out to be 1.74 Ohm. For example a more expensive transistor having a value R_{on} of, for example, 5 mOhms is selected for main switch SW1, which has to guide the continuous current. Especially expedient is a composite carbon resistor, because one like this is substantially more robust than a sheet resistor or wire-wound resistor.

In Figure 2 an additional FET switch, which is connected in parallel to main switch SW1, is indicated by dashed lines. Thus, expression is given to two different kinds.

In the first place, such an auxiliary switch H1B may be provided in addition to main switch SW1 and auxiliary switch H1A, in some cases along with a series ballast resistor (not shown), in order to absorb the current surge along with Joulean heat in sequence with auxiliary switch H1A or parallel with it.

Secondly, such an auxiliary switch H1B could be used without ballast resistance in place of the series circuit R1A – H1A, so that auxiliary switch H1B may absorb the current/heat surge when main switch SW1 is switched off. For this purpose, main switch SW1 and auxiliary switch

H1B are to be triggered by monitoring circuit UWE in such a manner that, in the event of an overload, immediately auxiliary switch H1B is switched on and main switch SW1 is switched off.

The variant according to Figure 3 represents an especially simple possibility for an automatic triggering of two parallel switches, specifically main switch SW1 and auxiliary switch H1A using a Zener diode, the circuit in other respects corresponding completely to the one according to Figure 2.

A circuit of this type is indicated especially if the auxiliary switch has a substantially higher internal resistance than the main switch, e.g., R_{on} =5 mOhms for the main switch and R_{on} = 100 mOhms for the auxiliary switch.

Monitoring unit UWE has, for example, an operational amplifying circuit with a PI controller action, so that it acts like the drive unit of an electronic power source. As long as the limit current has not been reached, the monitoring unit or its operational amplifier attempts to increase the limit current even more by further increasing the gate voltage of the switches or transistors SW1, H1A.

Because the output current of the power supply is determined by connected load LAS, the output of the aforementioned operational amplifier during normal operation will remain in positive saturation, for example, at 15 volts. Upon exceeding the set limit current – this may be, for example, 130% of the nominal current that set using a potentiometer on a dial – the operational amplifier becomes active and monitoring unit UWE then lowers its output signal, namely the gate voltage of MOSFET transistors SW1, H1A in order not to allow the output current to increase further.

As is evident, the output of monitoring circuit UWE is directly connected to the gate of auxiliary switch H1A and connected via a Zener diode ZD1 to the gate of main switch SW1. The gate voltage of the main switch, because of the Zener diodes, then reaches the threshold voltage earlier, that is, the voltage at which an FET becomes significantly more resistant even when the gate voltage drops only slightly, in other words, the beginning of the linear operational state in which the transistor acts like a variable resistor. In this way it is ensured that auxiliary transistor H1A in the limit case always absorbs as much current from main switch SW1 as allowed by its own internal resistance and ballast resistor RA1, which is connected in series.

During normal continuous operation, the control voltage generated by monitoring unit UWE, that is, the voltage fed to the gates of the switch, is to be dimensioned in such a manner that main switch SW1 may be fully enabled, but auxiliary switch H1A is not destroyed. In practice one obtains a favorable dimensioning if the Zener voltage of diode ZD1 roughly corresponds to the threshold voltage, that is, approximately 3 volts, of the transistors that are used, in this case the MOSFET transistors.

The integral portion of the control characteristic of monitoring unit UWE is also expedient in order to compensate for the vacillation point when crossing over the Zener diode threshold without excessive deviations of output voltage UA1.